INVESTIGATION ON TRIBIOLOGICAL PROPERTIES OF GRAPHENE REINFORCED COPPER

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Keywords:

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Introduction:

The primary focus of the project is to investigate the tribological property of the graphene-copper composite. Copper is an excellent material for many applications which require good electrical conductivity such as connectors, integrated circuits and contact materials. The pure copper is easy to be oxidized even in normal conditions forming a nonconductive ceramic layer which reduce its electrical conductivity and also strength. Graphene is a single layer of carbon atoms arranged in a two-dimensional honeycomb lattice. Graphene has potential uses in a wide range of fields, including electronics, energy storage (like batteries and supercapacitors), composite materials, sensors etc. Graphene is one of the strongest materials known, with a tensile strength over 100 gigapascals.

Graphene also provides an excellent electrical and thermal conductivity, making it a promising material for electronics and energy applications. Hence, recently, attention has been paid to reinforce copper with different ceramics such as Al_2O_3, diamond, graphite, graphene and ZrO_2 to increase its strength and reduce its oxidation tendency. Graphene-copper composites are advanced materials that combine the exceptional properties of graphene with those of copper. The Cu-GNP composite improves the tensile strength and hardness of copper. The thermal conductivity of copper is further enhanced with graphene, aiding in efficient heat dissipation in electronics and thermal management applications.

Objectives:

- Reducing Friction of Coefficient (COF)
- Reducing Wear Loss

Methodology:

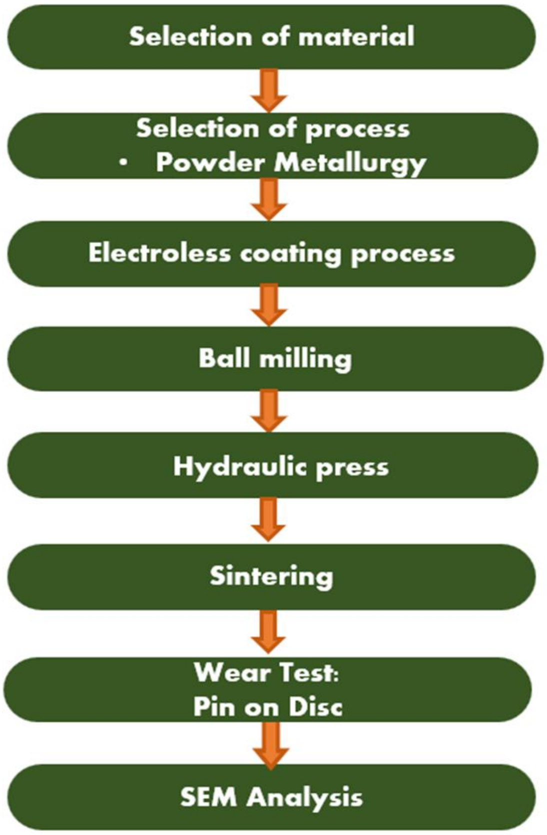

Figure 1: Methodology Flow Chart

The methodology followed in this project is as follows:

- **Selection of material:** the materials selected for this project are copper and graphene powder
- **Selection of process:** it's the process of selecting the best method to fabricate the specimen using the material selected. In this project the fabrication method

used is powder metallurgy, since the materials selected are copper and graphene powder

- **Electroless coating process:** A coating is a layer of material deposited onto a substrate to enhance the surface properties for corrosion and wear protection. In electroless nickel plating, a nickel coating is deposited on a surface using a controlled chemical process, or ‘reduction’, which is not based on an applied current.
- **Ball Malling:** Ball milling is a process that uses a rotating drum or container filled with balls, which is made of metal, ceramic, or glass, to grind, mix, or blend materials.
- **Hydraulic process:** Hydraulic press is the process of compacting metal powder in a die through the application of high pressures. Typically, the tools are held in the vertical orientation with the punch tool forming the bottom of the cavity. The powder is then compacted into a shape and then ejected from the die cavity.
- **Sintering:** Sintering is the process of taking metal in the form of a powder and placing it into a mold or die. Once compacted into the mold the material is placed under a high heat for a long period of time. Under heat, bonding takes place between the porous aggregate particles and once cooled the powder has bonded to form a solid piece.
- **Wear Test:** The pin-on-disc test is a standard method used to evaluate the friction and wear behaviour of materials. In this test, a stationary pin is pressed against a rotating disc under a controlled load and speed. The test provides insights into the tribological properties (friction, wear rate, and wear mechanisms) of materials.
- **SEM Analysis:** SEM (Scanning Electron Microscopy) analysis is a technique used to produce high-resolution images of the surface topography and composition of materials.

Result and Conclusion:

(a**) Effect of graphene on friction coefficient of Cu-GNP composites**

Typical behaviour is noted as it can be seen for COF decrease with GNP content increasing in the Cu matrix. For an example, Cu-0.40 wt.% GNP and Cu-1.0 wt.% GNP had COF of 0.44 and 0.26, respectively, which indicates considerable decrease in the frictional resistance. In addition, the COF of Cu-1.5 wt.% GNP was surprisingly stable during the testing period, at around 0.23, which was only slightly more than that of Cu-0.20 wt.% GNP. More particularly, this result is remarkable since it amounts to a reduced almost by 62% of COF in linkage with pure copper.

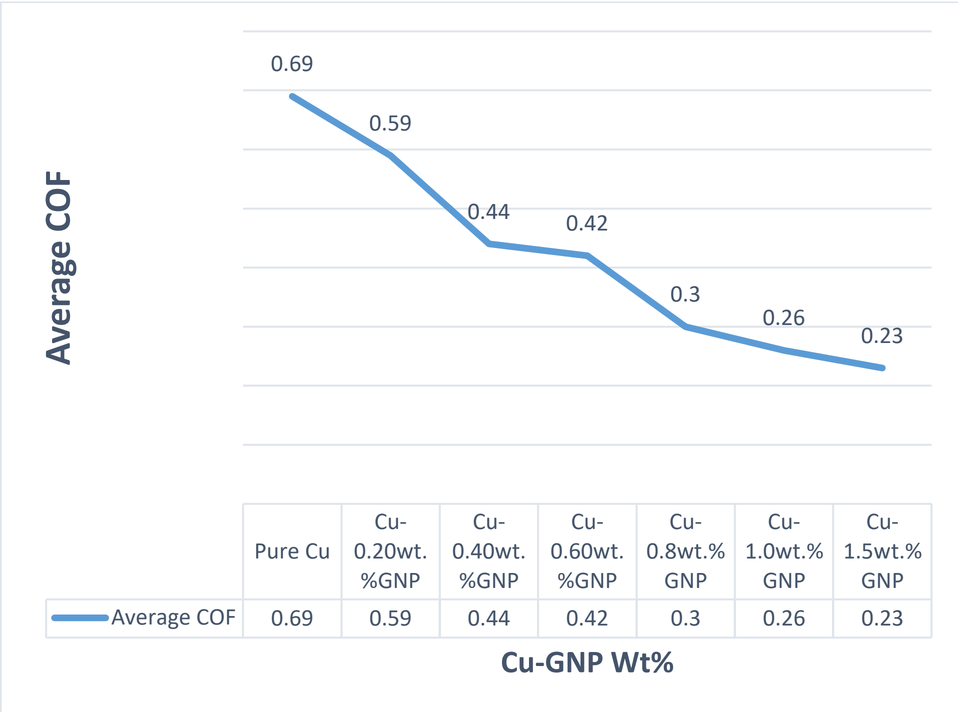

Figure 2: graphical representation of Average COF

Graph 1.1 Average COF of various Cu-Gr Wt%

(b) Effect of graphene content on wear loss of Cu-GNP composites

The trend of wear loss shows that with the increase of GNPs there is a reduction in wear in the composites. Therefore, it is observed that the inclusion of GNPs has significantly improved the wear properties of the material.

In addition, the Wear loss of Cu-1.5 wt.% GNP was surprisingly stable during the testing period, at around 0.070, which was only slightly more than that of Cu-1.0 wt.% GNP. More particularly, this result is remarkable since it amounts to a reduced almost by 56 % of Wear less in linkage with pure copper.

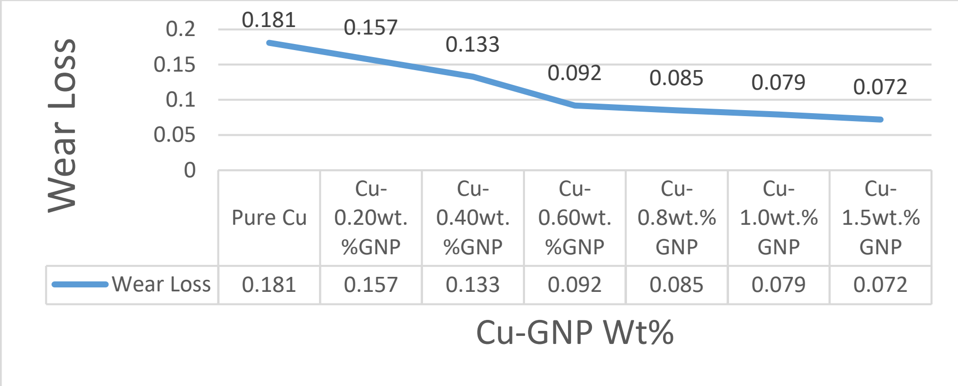

Figure 3: Graphical Representation Of Wear Loss

Graph 1.2 of Average Wear loss of various s Cu-Gr Wt%

Project Outcome & Industry Relevance

The industrial relevance of copper reinforced with graphene is substantial across several sectors:

- **Electrical Components:** The current-carrying capabilities combined with improved tribological properties make these composites suitable for applications where both electrical conductivity and mechanical durability are required, such as in electrical connectors and sliding contacts.
- **Mechanical Engineering:** Enhanced wear resistance and lubrication can benefit components subject to friction, such as bearings, gears, and other moving parts. This could lead to increased component lifespan and reduced maintenance needs.
- **Aerospace and Automotive**: In high-performance applications, the combination of improved tribological properties and potential weight reduction (due to graphene's high strength-to-weight ratio) can be advantageous for reducing energy consumption and enhancing overall efficiency.

Future Scope:

The future scope of this project includes:

1. **Optimization of GNP Content**

   Further investigation is needed to determine the optimal weight percentage of GNP in Cu composites that balances both friction reduction and wear resistance. Exploring other weight percentages around 1.5wt% could reveal even better performance characteristics.

2. **Mechanical and Thermal Properties**
   In addition to tribological properties, it is crucial to evaluate the mechanical (e.g., tensile strength, hardness) and thermal (e.g., thermal conductivity, thermal stability) properties of these composites to ensure they meet the requirements for various industrial applications.

Project Outcome & Industry Relevance Future Scope

The aim of this study is to improve the Tribological Properties of Cu composites by introducing GNP nanoparticles as a reinforcing material. This research will be a foundation for further investigations. Following this work requires continued efforts to build upon this work and to continue to improve the properties of Cu-GNP composites.

Several avenues exist to extend and enhance the current research:

1. **Alignment of Reinforcement Particles:** The attrition processes were capable of aligning the reinforcement particles Cu and GNP during the mixing process. While some reports exist for aluminum based composites, reports of fabricating Cu-GNP composites with aligned graphene particles simply does not exist yet.

2. Combination of Mixing Techniques: More uniform dispersion and a method of avoiding structural defects in the reinforcing material is possible by combining dry and wet mixing techniques for powder milling.

3. **Finite Element Method (FEM) Analysis:** Experimental results can be correlated with theoretical findings through modeling and analysis using FEM software.